TRENTON FALLS HYDROELECTRIC STATION,
POWERHOUSES AND SUBSTATION
On west bank of West Canada Creek, along
Trenton Falls Road 1.25 miles north
of New York Route 28
Trenton
Oneida County
New York

HAER No. NY-155-A

HAER
NY
33-TREN,
1A-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Northeast Region
U.S. Custom House
200 Chestnut Street
Philadelphia, PA 19106

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Location:	On west bank of West Canada Creek, along Trenton Falls Road 1.25 miles north of New York Route 28 Trenton Falls Oneida County New York USGS Quadrangle: Remsen, New York UTM Coordinates: 18.487280.4791220
Dates of Construction and Major Modifications:	1899-1901 (Old Powerhouse) 1917-1921 (New Powerhouse, Substation) 1942 (Substation addition)
Contractors/Engineers: (1899-1901)	General Contractor, Utica Electric Light & Power Company; Project engineers, George A. Brackenridge (supervising engineer) and J.W. Jenkins (chief engineer); Turbines, I.P. Morris Company, Philadelphia, PA, and William M. White (design consultant); Generators, General Electric Company, Schenectady, NY; Crane, Reading Crane & Hoist Worsk, Reading, PA.
Contractors/Engineers: (1917-1921)	General Contractor, U.S. Structural Company, Dayton, OH; Project Engineers, Byron S. White (supervising engineer); Thomas E. Murray, George A. Orrok, Philip Torchio (consulting engineers); Turbines, Platt Iron Works, Dayton, OH (1917-1918), Hooven-Owens-Rentschler, Hamilton, OH (1921); Generators, Westinghouse Electric & Manufacturing Company; Crane, Cleveland Crane and Engineering Company.
Present owner:	Niagara Mohawk Power Corporation 300 Erie Boulevard West Syracuse, NY 13202
Present use:	In operation; turbine-generator units 1-4 out of service

Significance:

Strongly influenced by the earliest Niagara hydroelectric project, the 1901 Trenton Falls Station was installed in a spectacular gorge and was probably the highest-head contemporary plant in the eastern United States. A distinctly transitional station, Trenton Falls combined European-style turbines which soon proved outmoded with prescient, long-lived choices in electric generating and control equipment. The new powerhouse, added to the old one in 1919, reflected a generation of rapid development in hydroelectric station design and equipment. Together, the two powerhouses survive as a powerful example of technological and architectural change over a short period of time.

Project Information:

Trenton Falls Station is eligible for listing on the National Register of Historic Places. Niagara Mohawk Power Corporation proposed station modifications in the 1970s. As a result of project review by the Advisory Council on Historic Preservation, the New York State Historic Preservation Officer, and the Federal Energy Regulatory Commission (FERC), Niagara Mohawk will remove three of the four original turbine-generator units and stabilize powerhouse foundations. HAER documentation of the station, required by revised Article 35 of FERC license 2701 prior to such actions, was conducted from February to August 1993.

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Part I - Historical Information*

A full discussion of the history and significance of the Trenton Falls Station appears in HAER No. NY-155, including the principal equipment installed in the two station powerhouses. Niagara Mohawk Power Corporation personnel generally refer to these as the "old" and "new" powerhouses, a usage retained here to reflect the difficulty in assigning a single date of construction or completion to the second structure.

Utica Electric Light and Power Company built the old powerhouse on West Canada Creek between 1899 and 1901, at what was then the highest-head installation of reaction turbines in the United States (about 265 feet). Heavily influenced by turbine design at the 1895 Niagara Station No. 1, the old Trenton Falls powerhouse included highly-engineered, European-styled turbines built or adapted by American engineers and turbine builders who were deeply involved in the Niagara project. The four Fourneyron turbines driving the old powerhouse's main generators, and the two Girard turbines driving its exciters, proved to be technological dead ends rather than significant engineering achievements. With hydroelectrical turbine installations undergoing rapid transitions during the period of old powerhouse construction, the design shortcomings of the first Niagara station's turbines were not at the time so widely known in the engineering fraternity. Had Utica Electric Light and Power waited another few years to build at Trenton Falls, the turbines chosen would likely have been quite different from the package presented by supervising engineer George Brackenridge in 1899.

In contrast to the turbines, the 1899-1901 electrical operating systems and equipment represent durable although not necessarily highly unusual choices. Clearly a transitional installation, the old powerhouse also combined older technologies with the then-novel Eastern American use of high-head generation, notably in the varied and extensive use of water power for many plant operations. Station designers were perhaps not fully trustful of their new technology, relying on the more proven hydromechanical drives for turbine gate valves, water pumps, station service generator, and governor operating cylinders. Soon after this station was built, all such auxiliaries would have been powered by electric motors.

There were few documented modifications at the old powerhouse before 1917. The basic operating regime was greatly simplified by the fact that, for the four relatively small units originally installed, there was usually abundant water at a nearly constant head and with constant tailwater conditions. Plant operators probably soon discovered the primary shortcoming of the Fourneyron units, their serious loss of efficiency at part gate, and simply elected to operate them at full gate or turn them off. By so doing, they partially eliminated problems of abrasion and high pressure encountered in using penstock water as the operating cylinder fluid for the Porter-Allen governors. Rather than switch to a more common cylinder fluid of pump-supplied pressurized oil, plant operators by 1917 piped in water from a spring several hundred feet

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* Capitalized, undated references are to photographs in this documentation.

northwest of the powerhouse, and pressurized it with two small I.P. Morris centrifugal pumps driven by penstock-water-powered Pelton wheels mounted in the basement gallery next to the river. The two Girard exciter turbines also developed some problems soon after powerhouse completion, because in 1904 they were supplemented by a 115-hp Pelton-wheel-driven generator.[1]

Although planning for expansion began soon after old powerhouse completion, sufficient additional water supply was not assured until after the 1914 completion of the state-owned Hinckley Reservoir, upstream on West Canada Creek, for the Barge Canal. Increased electrical demand during World War I, even prior to formal American involvement, was a nationwide phenomenon which finally sparked the expansion of Trenton Falls Station. Utica Gas and Electric Company (UGEC), the immediate successor to the firm which built the old powerhouse, began the new powerhouse in 1917 and completed it in 1919. One bay of the old powerhouse was removed for the new one, built immediately adjacent. Two of three turbines and most electrical apparatus were installed in 1918-19, but the new powerhouse was not fully equipped until the early 1920s.

In contrast to the old powerhouse turbines, units 5-7 in the new powerhouse are simple, functional, generic Francis turbines, like hundreds of others installed at similar sites world-wide in the past ninety years. One of the most startling differences is the small size increment between the two sets of turbines. The Francis units generate about six times the power of the Fourneyrons, with runners only four inches greater in diameter (57 vs. 53 inches). Where units 1-4 have separate exciters driven by relatively large, complicated Girard Turbines, the Francis units have exciters built onto the tops of their generators. If built to the same power-to-size ratios as units 1-4, units 5-7 would be four times their actual size.

In 1931, inspections at Trenton Falls revealed significant leakages from the pipeline and gate valves serving the old powerhouse, losses of head through the two intakes feeding the larger pipeline to the new powerhouse, and friction losses in the latter pipeline which analysis indicated could be overcome by opening four remaining unused intakes at the dam. After considering closing the old powerhouse or running both powerhouses from the larger pipeline, UGEC rebuilt the old pipeline and completed other improvements in 1931-32 which increased total station capacity to some 27,500 kw (a 5% increase) and upgraded safety and hydraulic control features. These improvement included repair and upgrading of turbines 1-4, with electric-motor-driven gear-reduction units replacing original Pelton-wheel gate valve operators, welding and restoration of pitted bronze runner surfaces, and replacement of the pressurized-water governors with variable-speed DC motors linked to Westinghouse speed-sensing relays atop each generator. Several years later, UGEC upgraded gate valve operators and governors on units 5-7, the former with replacement by motor-driven butterfly valve operated through Limitorque drives, the latter by replacing the original Lombard flyball head and oil pumps with more modern Woodward units, while retaining the Lombard operating cylinders. Aside from runner replacements, the last significant changes in turbine hardware occurred in 1965 when the manually-operated brakes, operating against a pulley above each runner in units 5-7, were modernized by the addition of an air compressor and air cylinders to allow remote operation.[2]

The Trenton Falls Station today is most significant as a fascinating study in contrasts between two very different generations of hydroelectrical engineering, physically juxtaposed in one powerhouse structure. Aside from the unusual old powerhouse turbines, each powerhouse is typical of hydroelectrical developments with vertical turbine-generator installations made during its period of construction, including the common use of foundations as hydraulic structures, with intakes, draft tubes, and tailraces set or formed within concrete. Dramatic differences in the scale and style of the two powerhouses immediately highlight the major episodes of equipment design, construction, and installation. Although both steel framed, the powerhouses have very different surface treatments. Old powerhouse use of a hipped roof, a Renaissance Revival masonry exterior, and relatively elaborate interior brick treatments reflect the builders' sense of the project's importance, often seen in major stations before c1915. The more utilitarian reinforced concrete of the new powerhouse is one of several common designs which replaced this older style by World War I. Old powerhouse incorporation of all transformation functions within one structure contrasts with the new powerhouse use of an outdoor substation, a development beginning c1913 as higher voltages increased conductor clearances and fears of fire. The other differences in electrical controls described below are entirely typical of changes made during a period of rapid transformation in the electrical industry.[3]

Units 1-4 and their Girard exciters are the last surviving utility plant examples of two turbine types that never became popular due to high manufacturing costs and design limitations. Units 5-7 are early examples of a revolution in turbine design, re-establishing American dominance in the field that would last until the 1980s. The Fourneyron is only a footnote of historical interest in most books on turbine evolution, the Girard even more obscure, but here in one small building they remain in one of their finest installations in North America. Seldom do quirks of technology survive in such style.

The survival of some original Trenton Falls electrical equipment reflects the quality of design decisions in a pivotal period; of extant Niagara Mohawk 60-cps stations retaining original equipment, few if any are older. Continual change has not left the old powerhouse an intact specimen of c1900 design, however. New powerhouse revision of old powerhouse control systems modified or eliminated original air blast transformers, low and high tension switches and transmission towers, until today the generators and exciters are the only major surviving pieces of original electrical gear. The survival of the original generators and exciters without the control or transmission equipment is not unusual; rotating machinery of the period often achieved efficiencies of 98% -- levels hard to equal today. The original generators are also beautiful examples of contemporary heavy electrical engineering, with the flared bases and rounded tops of the stator shells soon to give way to more hard-edged utilitarian designs. The machines were massively overbuilt, partially explaining their long life-span. By contrast, the original switchgear and transformers were both fragile and dangerous by modern standards. High-tension circuit- breakers near the control boards exposed operators to electrocution and fire hazards. Numerous auxiliaries were controlled by hand-operated carbon circuit breakers which could flash and disintegrate under severe overloads. Indoor transformers required high tension leads to be brought into the building with attendant risks.

The new powerhouse represents a period of increasing sophistication in electrical control. Switchboards were equipped with low-voltage remote control of distant high voltage switches. Protective devices monitored all functions of the generators, allowing operators to run entire stations without leaving the board area. This generation of technology allowed for largely unmodernized operations to the present time, one reason why the new powerhouse -- while in almost original condition -- is by itself neither especially significant nor unique. Coupled with the old powerhouse, however, the new one gives Trenton Falls Station a generation-spanning quality rarely seen elsewhere.

Part II - Descriptive Information

Summary of Site Arrangement and Existing Conditions

Trenton Falls Station encompasses about 40 acres along West Canada Creek (see HAER No. NY-155). The powerhouses and substation at the southern end of the complex cover about 2 acres, at two dramatically different elevations. At the bottom of Trenton Falls Gorge lie the two powerhouses, cut into the steep limestone slope. The gorge top is ninety feet above the generator floor of the powerhouses, and extends several hundred feet to the west on a relatively level surface. On this surface are the substation, a small transmission tower, and the remnant original steel pipeline sections which feed the powerhouse penstocks with water from the 14-foot-diameter 1984 pipeline. Four steel penstocks -- one to the old powerhouse, three to the new one -- swoop down the slope. The Trenton Falls Road station entrance passes a recent brick Niagara Mohawk garage-office and leads to the dense array of substation, pipelines, and wire catenaries linked to the new powerhouse, but from the west side of West Canada Creek the powerhouses are largely hidden until one comes to the edge of the gorge.

There are two normal means of access to the powerhouses. A roadway running about 1300 feet south from the old powerhouse hugs the edge of the creek and rises to the southwest to meet Trenton Falls Road, immediately north of the intake to the Nine Mile Creek Feeder of the New York State Barge Canal system. The access road originated as a narrow-gauge railroad track used to install original old powerhouse equipment. Masonry and concrete retaining walls support much of the access road, widened in recent years by removal of more gorge wall. The masonry walls, described below, were part of c1899-1901 construction; the concrete sections were first installed in 1941 and later extended or repaired. The second access route is via a stairway and elevator tower, rising from the southwest corner of the new powerhouse to a steel foot bridge which joins the tower to the upper gorge surface.[4]

With the exception of upgrades made to hydraulic and electrical controls, detailed below, the powerhouses remain very much as they were after new powerhouse construction, which created a structure 228.8 by 37.2 feet with auxiliary components discussed below. All nine turbines are set below the main or generator floor level, on which the seven generators and various hydraulic controls sit. The principal exterior alterations have been the 1942 removal of a lightning arrester house built for the old powerhouse, and modifications made to the access road retaining wall and adjacent gorge walls. The penstocks and pipelines south of the 1984 pipeline are original fabric dating from 1901 and 1931, but lack the original standpipe and surge tank (see HAER No. NY-155). The substation, today about 160 by 40 feet in area, retains steel frame components from several generations of construction, probably including the earliest c1917-19, but Niagara Mohawk plans call for 1994 removal of older substation components.

Old Powerhouse

As originally built, the first Trenton Falls powerhouse was 137.8 feet long and 37.2 feet wide. The single-story, steel-framed, brick- and stone-clad superstructure had a metal-tiled hipped roof, and a massive concrete-and-rubble foundation faced with stone and built around turbine pits and tailraces. Although set deep within the gorge, the powerhouse site was much more publicly accessible in 1899 than today, and the gorge still retained fame as a natural wonder. These factors, and the hydroelectric station's importance to its developers as a very high-head site with heavily engineered turbines, may explain the relatively lavish interior and exterior surface treatments. The old powerhouse's integrity was somewhat compromised by the abutting new powerhouse, for which the northern bay of the older structure was removed, reducing its present length to 120 feet.

Substructure

Powerhouse foundations rest on an excavated, multi-level surface of limestone bedrock at the bottom and side of the gorge, including an area behind the powerhouse for the manifold or receiver which connects the main penstock to the individual turbine intakes. Along the original northern 95 feet of the old powerhouse, part of which is now within the new powerhouse, the bedrock under the powerhouse proper has a two-step east-west section. The higher step to the west is nearly 14 feet below the generator floor, and was excavated to the bottom level of the turbine penstocks. The lower step, closest to the creek, is 24 feet below the generator floor of the superstructure, and was excavated to the bottom level of the turbine tailraces slightly above the rock creek bottom. This deeper space, over 20 feet wide and largely filled with concrete and crushed bedrock fill, accommodates the turbines, draft tubes, other turbine-related apparatus described below, and four tailraces. The 6.5-foot-wide, 8-foot-high brick tailraces have concrete, segmentally-arched tops. The main turbine-generator units, numbered 1-4 from south to north, are set at 18-foot centers along the longitudinal center of the powerhouse, with the turbine-exciter units placed southwest of units 1 and 2.[5]

Except for voids created for the four main turbines, the longitudinal center of the 95-foot-long northern foundation section is a 16-foot-wide, 23-foot-high concrete pier. East of this pier, crushed rock fill retained by an outer river wall supports a 7.9-foot-wide, 6.8-foot-high concrete-sided and -roofed basement passageway with an arched top. A 2.8-foot-wide stairway with a brass rail rises from the south end of the passageway to the generator floor. West of the central pier, the 6-foot-wide concrete wall which forms the west side of the foundation retains additional crushed rock fill. For a 70-foot distance on the west side, there is a narrow passageway about 5 feet wide, similar in height and material to the eastern passageway, with alcoves exposing the upper casings of the six main and exciter turbines described below. A stairway similar to that for the eastern passageway links the middle of the western gallery with the generator floor.[6]

The southern 42 feet of the old powerhouse foundation appears from available plans to rest on a single bedrock step 8 feet below the generator floor, and consists of a concrete-floor space subdivided by concrete walls into a 32-by-16-foot machine shop (originally with now-removed locker room and toilet facilities), a 41-by-7.7-foot area formerly used as a switch room described below, and a 40-by-5-foot area formerly used for air ducts serving air-blast transformers described below.[7]

The 24-foot-high river wall running along the entire east side of the foundation consists of large, rock-faced ashlar Gouverneur marble blocks bonded to concrete. Flat-topped segmental stone arches highlight the tops of the tailrace openings in the wall, which is 7 feet thick at its base, and extends about 40 feet south of the powerhouse with a short return at the end of the access road. The wall originally extended north of the powerhouse to support foundations of a poorly-documented boiler house noted below; this section was removed for the new powerhouse. Niagara Mohawk reinforced and repointed the southern section of the wall in the mid-1980s.[8]

Behind the powerhouse, bedrock was excavated to an elevation about 16 feet below the generator floor for the penstock manifold, created a space 11-to-19 feet wide. A yellow-pine platform spans this space at the generator floor elevation, supported by 8-by-8-inch steel channels on brick piers at 8- and 10-foot centers. By the time the new powerhouse was completed, a 1-to-5-inch-thick concrete slab covered most of this platform, along with the remaining narrow space between the gorge wall and both powerhouses.[9]

Superstructure

The foundations support a 4-inch-thick concrete generator floor, with 18-inch-thick stone bases under the generators. Above the floor, the steel-framed superstructure rises 23 feet to the bottom of the W-shaped steel roof trusses, which support a steel-framed, wood-decked roof 14 feet high. Although elaborately finished, the superstructure is a large open shell covering the equipment inside.

Composite 18-inch-square steel I-beam columns, bolted to the foundations and flanged to support 20-inch I-beam crane rails, originally created nine longitudinal and two transverse bays. New powerhouse construction removed the northern transverse bays and one longitudinal bay. Transverse bays have 18.6-foot centers; all longitudinal bays have 15-foot centers except the endmost, which are 15.3 feet between column centers. Steel angles form the roof trusses between column heads, and support steel channel jack rafters and I-beam purlins to frame the roof.[10]

Powerhouse walls, at least 26 inches thick, have rugged, Renaissance Revival exteriors of rock-faced, irregularly-coursed Gouverneur marble ashlar blocks, highlighted by a large round-arched window or door in each bay, and 8-inch-deep, 28-inch-wide rectangular pilasters between bays. Marble blocks are somewhat smaller and more finished than those used in the retaining wall below. Beveled marble blocks form window sills, and a continuous base course encompassing the modified Doric pilasters. Above the minimal pilaster capitals, there is a dentillated, three-coursed, plain entablature and a two-course rounded cornice. The surviving southern door opening has a 3-inch-thick, 11-foot-wide, 9.3-foot high double wood door with recessed, diagonally-boarded panels, beneath a 5.5-foot-radius transom with movable sash. Above the door, a relief-carved marble block announces:

U·E·L·&P·C°
1900

The wood windows, set in each longitudinal and one transverse bay, are 7.5 feet wide, each with a 7.2-foot-high, tripartite set of paired, 2-over-2 windows beneath a 3.3-foot-radius tripartite transom with a central pivoting panel.[11]

The simple but elegant interior walls have two courses of brown enamelled brick at window sill levels, separating white enamelled brick below and cream-painted pressed brick above. On the long walls, each 3-foot-high column flange, ending 18 feet above the floor to support the crane rails, has a flat (probably wrought iron) casing, below which is a decorative wrought-iron *torchere* with five incandescent lights. A triple *torchere* decorates the south end wall at a similar elevation. The roof interior and trusses, today painted white, originally had white roof boards contrasting with dark-painted steel members. Red metal tile originally covered the 4-by-6-inch tongue-and-groove roof boards; today channelled sheet metal forms the roof surface.[12]

Auxiliary Structures

There were two nearby, detached, scaled-down versions of the powerhouse: a 41-by-20-foot boiler house to the north at the generator-floor elevation, supplying heat to the powerhouse and pipeline surge tank or vent structures (see HAER No. NY-155); and a 25-by-13-foot lightning arrester house to the southwest on an approximately 20-foot-high platform of rock fill and marble-block walls. As described below, the lightning arrester house was demolished in 1941; fragments of the high foundation remain.[13]

Operating Equipment

Penstocks

The principal penstock is a continuation of the 7-foot-diameter riveted-steel pipeline from the dam and headworks, and runs down the slope from the top of the gorge for about 100 feet, passing through the platform behind the powerhouse to an elevation about 6 feet below the generator floor (see HAER No. NY-155). At this elevation, the penstock enters a 60-foot-long, 7-foot-inside-diameter, riveted-steel manifold or receiver which runs parallel to the west powerhouse wall, with a centerline elevation 11 feet below the generator floor. This is also the centerline elevation for four 4-foot-diameter, 6-foot-long steel penstocks feeding units 1-4, running to gate valves described immediately below. Twelve 10-to-14-foot-long, 4-to-10-foot wide concrete saddle piers support the receiver. The high-pressure water entering the receiver also served fire lines, as well as auxiliary hydromechanical systems for gate valve and the exciter generator installed soon after the station opened. Eight-inch Ross automatic air valves were installed on the receiver.[14]

Turbines and Hydraulic Controls

The gate valves controlling flow to units 1-4 are original, 48-inch units comprised of Eddy Valve Company housings with Coffin Company internal components. The original operating system used a 30-inch Pelton wheel with a 7:1 gear reduction set to drive the gates through line shafting mounted 42 inches off the generator floor, arranged so as to allow the four valves to be operated separately or in unison. This was replaced in 1932 with massive, 7 1/2-hp electric-motor-driven gear-reduction units mounted on the stem of each valve. There is a small manually-operated gate valve on a by-pass pipe loop around each gate valve to make operation easier against full head pressure.[15]

The main generating turbines are vertical-shaft, outward-radial-discharge reaction turbines of the Fourneyron type, with external cylinder gate throttling, bronze runners, pressurized oil lubrication and generators directly mounted above the turbines on hanging thrust type bearings.* The 53-inch-diameter runners are each 6 1/8 inches high (wetted area) on a 48-inch shaft, flange-coupled to the generator. Each runner has 37 buckets, each 5 1/2 inches high and 13/16 inches wide at narrowest section. The turbine units themselves are completely below the generator floor level, visible through holes in the generator mounting base plate, and partly accessible in alcoves along the basement gallery, where the top of each housing containing the somewhat complicated cylinder gate mechanism is visible. The turbine housing itself is dwarfed by the arms, levers, and rods necessary to translate governor motion (or, now, actuator motion) into movement of the gate. Turbines 1-4 develop approximately 1700 horsepower under a head of 265 feet, at a speed of 360 rpm. Turbine discharge funnels into essentially cylindrical draft tubes, returning the water to the river through the tailraces described above.[16]

Original installation for each Fourneyron unit included a Porter-Allen governor, set about 3 feet south of the manual actuators (converted c1932 to motorized gate actuators). A pair of spur gears on the turbine shaft drove a small jack pulley which in turn powered a long leather belt off a small jack pulley to drive the flyball unit. A slot in the generator base allowed for the belt. The flyball unit of the governor controlled the flow of penstock water at 130 psi to the vertical operating cylinder of the governor, which moved the linkage going through the floor to raise and lower the long arm controlling the turbine gate itself.

Plant operators probably soon discovered the primary shortcoming of the Fourneyron units, their serious loss of efficiency at part gate, and simply elected to operate them at full gate or turn them off. By so doing, they partially eliminated problems of abrasion and high pressure encountered in using penstock water as the operating cylinder fluid for the Porter-Allen governors. The penstock water, loaded with fine, highly abrasive sand, quickly wore down cylinder gate sliding surfaces. Penstock water pressure was apparently higher than anticipated, or forces were miscalculated, and the governor moved the turbine cylinder gate too fast and too hard. Rather than switch to a more common cylinder fluid of pump-supplied pressurized oil, plant operators by 1917 piped in water from a spring several hundred feet northwest of the powerhouse, and pressurized it with two small I.P. Morris centrifugal pumps driven by penstock-water-powered Pelton wheels mounted in the basement gallery next to the river.[17]

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* These bearings are similar to those used in the early Niagara installations. Some hanging bearings used a film of oil forced at 400 psi between a revolving disk on the shaft above and a fixed disk on the bearing seat. In another variety, oil pumped to the bearing center spread centrifugally between the disks. The variety at Trenton Falls was not documented, although the oil pump type (see page 13) suggests the former. In either case the pressurized oil supported the entire weight of the generator (see Mead 1920: 253-7).

The original governors were completely removed in 1932, and replaced with variable-speed, 3/4-hp DC motors linked to Westinghouse speed-sensing releys atop each generator. The motors drive through a gear reduction unit attached to the original rack-and-pinion manual gats operating mechanisms. The speed sensing relays are mounted in small tin cens.[18]

The two exciter turbines are vertical shaft, radial outward discharge turbines of the Girard type. There are three throttling systems: a manual 12-inch gete valve on short penstocks tapped off the penstock of the adjacent Fourneyron; a spool-valve unit apparently added about 1906;[19] and an internal register gete within ths overhung-style runner itself, operated by the shafts and pairs of bevel geers visible on the top of the turbine housing. The added spool-valve may reflect early problems with the register gate. Each 21-inch-diameter runner is finely-machined cast bronze, and produced 100 hp et 750 rpm at a listed operating head (after piping losses) of 250 feet. One Girard is now partially disassembled, with its runner resting in the basement hallway beneath the transformer/relay area.

The general arrangement of the exciter units mirrors that of the main units, with direct coupling to generators on the main floor above, end the turbines set in small alcoves off the main turbine basement gallery. Each Girard is mounted in a large cast-iron case with a very substantial bridge bearing above the case. The two manual water-flow valve operating rods extend down through the floor to the units with short intermediate links. Piping for the preesurized-oil bearing lubricating and cooling system complete the visible components. Water passing through the Girards was presumably piped to the nearest Fourneryon tailrace, although no information on this point emerged in research for this documentation.

A third exciter turbine-generator in the old powerhouse, added c1904, remains in original position but now lies at the south end of the new powerhouse. It is powered by a tangential-flow impulse wheel of the Pelton type, designed and built by the Pelton Water Wheel Co. (Pelton Co. M-603). This is a double-runner unit with two identical 24-inch-diameter runners, mounted side by side on the same axle and fed by two manually-operated 4-inch gate valves. The turbine spins at 500 rpm, producing 115 hp to drive the 85-kw General Electric generator. The runner is housed in a simple cast-iron housing, and was originally fed water from a 10-inch-diameter pipe tapped off the main manifold or receiver feeding units 1-4. After new powerhouse construction, the water feed wes transferred to the penstock for unit 5. The wheel discharges into an 18-inch-diameter vitreous tile drain to the creek, running through rock immediately north of the powerhouse.[20]

Exciter No. 3 supplemented the two Girard exciters, following e problem identified soon after the plant opened, and could eesily provide excitation for units 1-4 by itself. The most obvious potential problems with the Girerds would be their vulnerability to even small pieces of trash in the penstock water, caused by the small size of the water passages in the nozzle and regulating valvs, and aggravated by the difficulty of opening the turbine casing to clean the water passages of trash. The Pelton design itself is immune to most trash, only the external nozzle being susceptible, but easily cleaned.

The bearing lubricating system for the four Fourneyrons and two Girards is now handled with a Deane triplex piston pump in the basement gallery closest to the river, with an oil pipe on the gallery wall opposite the pump, beneath electrical conduit. This pump dates to 1916; there is no available information on the original oil pump. Oil tanks and filters are located in a steel framework on the west wall of the generator floor, behind unit 4.

Generators, Electrical Controls, and Transmission Facilities

The main generators are substantially in original condition. Units 1-4 are General Electric A.C., vertical (umbrella) type ATB, class 20-1000-360, Form A, rated at 1000 kw, 2200 volts, 263 rpm, 3 phase, and 60 cps, with serial nos. 57981-3 and 69654. Nameplate patent dates, on the 13.8-foot-diameter, 5.4-foot-high cast-iron stator shells, cover 1888-1899. The use of vertical style of generators was governed by the choice of turbine. Documented alterations appear limited to some rewinding and reinsulating of field coils, and the 1932 addition of a speed-sensing relay on top of each unit to control the turbine actuators.[21]

The original two Girard-driven exciters, for energizing the main generator field magnets, are also virtually original in condition. They are General Electric vertical type MP, class 4-85-750, form V, 680 Amps, 125 volts, 85 kw, 750 rpm, serial nos. 34035 and 34036. Nameplate patent dates cover 1882-1896. The Pelton-driven third exciter, added c1904, is a General Electric 85-kw horizontal unit.[22]

The main generators outputted to a control and transformation section in the south end of the plant. No equipment, equipment records, or detail drawings from this section survive. Available floor plans and historic views allow for an accurate general description, however. Power from the generators was routed around the station via copper wires, in porcelain ducts embedded in the concrete floors and in pipe conduit along the west wall of the eastern basement gallery. Power passed first to low-tension generator circuit breakers, which were double break-plunger types developed by Westinghouse. A handle on the board front closed and opened multiple contacts mounted on the rear surface of the board.[23] After passing through the first set of circuit breakers, power went to a bank of six 666-kw air blast transformers. These were the standard indoor large-capacity voltage changing devices of the period. They were mounted over a chamber pressurized by air from two fans. Air entered the transformer bases and carried the heat of transformation out the tops. The transformers stepped up the voltage from 2200 to 22,000, which then went though a set of circuit breakers of the oil type.* The high tension OCBs were probably located in a switch room in the basement, controlled by mechanical or electrical switches on a high-tension switchboard near the transformers on the generator floor.

The stepped-up power went out of the building to the lightning arrester house, and up to an adjacent transmission tower, with lines going across the creek and southwest.[24] Niagara Mohawk drawings and documents do not describe the lightning arrester house, but a similar structure at the 1899 Mount Whitney station in California suggests the lighting arrester units consisted of six choke coils (hourglass-shaped spirals of wire) in series with the line and 30 gap-type arresters mounted on a marble slab.[25]

New powerhouse construction included consolidation of control apparatus and low-tension output between both powerhouses, and initiated removal of old powerhouse electrical controls (discussed with new powerhouse electrical controls below). The new generators (units 5-7) had a voltage of 13,500 which was stepped up to 44,000 in the new outdoor substation on the bluff west of the powerhouses. To unite the powerhouses electrically, three new 2000-KVA** airblast transformers were installed in the old powerhouse to step up the voltage to 13,500 to match new powerhouse output.[26] General Electric provided the new transformers, which were probably placed on the foundations of the older units.[27] Both powerhouses then sent the same voltage to the 44,000 volt substation, reducing old powerhouse output from 22,000 to 13,200 volts -- an unusual event in the history of electrical engineering. Control boards in the new powerhouse assumed control of units 1-4, accompanied by removal of the original old powerhouse switchboards. At some point after replacement of these boards, the basement switch room was abandoned, the wall separating this room from the basement gallery was removed, and the transformer air duct was sealed off or filled in.[28]

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* Oil circuit breakers (OCBs) came into use c1900 for switching high voltage AC currents (e.g., *Electrical World and Engineer* 1900). In this type of switch, contacts are made and broken in a tank of oil that quenches the arcs created when high tension circuits are opened. The mechanical force is provided by hand levers, compressed air, electric motors or solenoids (powerful coils that move the contacts by magnetic action). All the Trenton Falls OCBs are the solenoid type.

** Kilovolt Amperes is rating for electrical equipment based on potential capacity and is higher than the kilowatt rating. Old powerhouse generator ratings is in kw; new powerhouse units are rated in KVA, which came into general use c1915. KVA is the product of volts x amperes, divided by 1000, and is about 20% higher than the equivalent kw rating. KW ratings are affected by Power Factor, the electrical efficiency of the circuit expressed as the ratio of actual power to apparent power. KVA ratings are noted with the Power Factor figure as a percentage of 100 to provide more accurate pictures of real electrical equipment capacity (Shultz 1989: 235; Dawes 1928:158; Gray 1917: 215, 251).

In 1942, Central New York Power suppressed the indoor air-blast transformers and generated directly from units 1-4 to the substation, then being enlarged. A steel tower, 70.3 feet high and 65 inches square at the base, was built on a concrete plinth between the old powerhouse and the gorge wall to take 2200-v generator output to transformer bank 4. The old powerhouse thus incurred its second voltage drop. Rerouting the old powerhouse lines to the substation made the arrester house obsolete, and it was demolished at this time. The steel tower was demolished in 1992.[29]

Crane

In 1902, the Reading Crane and Hoist Works installed a 20-ton traveling crane on the crane rails above the generator floor, with hand travel and lift.[30]

New Powerhouse

The steel-framed, reinforced-concrete, 37.2-foot-wide, 108.8-foot-long powerhouse has two contiguous auxiliary structures: the 17.5-by-12-foot elevator-stair tower at the southwest corner, facing the gorge wall; and a 15-foot-high, 20.1-by-23.3-foot boiler house at the east corner of the north wall. The generator floor is continuous and open through both powerhouses. From the generator floor, the new powerhouse rises 51.2 feet to a second floor, and a total of 70.9 feet to the top of the roof parapet. From the top of the gorge, 90.1 feet above the generator floor, a 47-foot-long, 5-foot-wide, deck-trussed concrete bridge runs to the elevator-stair tower, above which point the tower and bridge support a 27-foot-high, 15-by-17.5-foot elevator penthouse.[31]

Substructure

Like the old powerhouse, the new one sits on an excavated bedrock shelf, in this case a uniform base about 23 feet below the generator floor. The concrete base probably includes some rock fill, but material reviewed for this documentation was not conclusive on this point or on any concrete reinforcing system. Penstocks, turbines, draft tubes, and elliptical, 8-by-6-foot tailraces are set within the foundation, at elevations identical to those in the old powerhouse. The turbine-generator units, numbered 5 to 7 south to north, are on 27-foot centers, in a line centered 3.3 feet west of the longitudinal center of the powerhouse. A basement level 10 feet below the generator floor, with a stairway connecting these levels at the station's northeast corner, includes a 7.5-foot-wide gallery along the east wall, continuous with the old powerhouse gallery but 2 feet lower; four steps join the old and new basement levels. The basement floor is just above the center-line elevations of the penstocks and turbine scroll cases, and continues around each turbine; 2-foot-thick discontinuous concrete walls around each turbine continue from the basement floor to the bottom of the generator floor, creating an open enclosure.[32]

The elevator-stair tower rests directly on an excavated bedrock surface at the generator floor elevation.

Superstructure

Networks of steel I-beams frame the main powerhouse walls. Columns 15 inches square are bolted through the 6-inch-thick concrete floor to create five longitudinal bays, spaced from north to south at 23.3-, 23.3-, 23.3-, 20-, and 15-foot centers. On the interior side of each column, 33.1-foot-high, 15-by-17-inch columns support 3-foot-high crane rails. There are no structural east-west bays; 4.6-by-2-foot girders span the generator floor area to frame the floor of the second level, along with 2-by-.5-foot north-south beams. The flat roof is framed east-west by 2.6-by-.8 foot beams, with 1.2-by-.4-foot beams running north-south.[33]

Except where interrupted by a switchboard gallery described below, the concrete walls are 2 feet thick to the top of the crane rails, and 16 inches thick above. Typical column casings are pilasters 2.3 feet wide, with depths of 13 inches inside and 6 inches outside. Down-curving metal incandescent lighting fixtures project from interior pilaster faces, at the elevation of the old powerhouse *torcheres*. Within the recessed wall panels created by the pilasters, horizontally-pivoting steel sash is arrayed in columns of varying number and width, beginning 26 feet above the generator floor. On the east and north sides, these windows rise 34.3 feet to light generator and second floors, with 4.1-foot-high cast-iron spandrels separating the floor levels. The west side, near the gorge wall, has 14.1-foot-high window columns. A cornice and parapet complete a classicized, tripartite division on the eastern elevation, with the windows set above the switchboard balcony. The old powerhouse, the elevator-stair tower, and the boiler house with its chimney break up the other three elevations visually. The south elevation has only two 9.3-by-5.2-foot windows at the upper level; four 6.8-foot-wide windows light the west side of the elevator-stair tower.[34]

Set 7.1 feet above the generator floor, a 13.8-foot wide switchboard gallery area runs the full length of the powerhouse, including a 6.8-foot-wide, 9.8-foot-high cantilevered balcony with 1-foot-thick concrete walls framed by steel angles. The balcony has an asbestos-shingle shed roof, and 6.9-foot-high, horizontally-pivoting steel sash which mirrors the horizontal spacing of the windows on the east powerhouse wall above. Accessed from the generator floor by short ell-shaped stairways, the gallery includes a 13-foot-long office and a toilet/washroom.[35]

Most of the upper powerhouse floor is divided longitudinally, with a 20-foot-wide, 90.3-foot-long high-tension switch room on the west side, and a series of 12.5-foot-wide rooms on the east side divided by plastered tile walls. The high-tension switch room also has employee lockers, probably installed after some apparatus was removed when remote controls were introduced here in the 1960s. From north to south, the east side includes a 23.8-foot-long lightning arrester room, a 46.3-foot-long generator field rheostat room, a 9.6-foot-long battery room, and a 9.6-foot-long acid room. There is also a toilet and shower in the southeast corner.[36]

The flat, tar-papered roof has a 12-inch-wide, 2.5-foot high parapet and five peaked, 6-foot-wide skylights centered over each powerhouse bay, centered 7.5 feet from the west wall.[37]
At the powerhouse north end, an 11.5-foot-wide, 12-foot-high pair of hollow metal doors provides access to the boiler house, which sits on a 38.5-by-31-foot concrete slab tapering to 6 feet wide. The slab rests on or just above bedrock, and is enclosed by a concrete wall averaging 13 feet high.[38]

Operating Equipment

Penstocks

From the reducing manifold at the end of the 12-foot-diameter pipeline from the dam and headwork, three riveted, 7-foot-diameter steel penstocks drop 106 feet on an angled path to the turbine gate valves. Each penstock rests on two concrete saddles. The Unit 5 penstock also feeds the No. 3 Pelton-wheel-driven exciter and the powerhouse water supply through pipes controlled by, respectively, 12- and 10-inch gate valves.[39]

Turbines and Hydraulic Controls

The original main valves ahead of each of the Francis turbines were hydraulically-operated Coffin 66-inch gate valves, with pressure for the hydraulic cylinder coming from penstock water. Each valve was a single disc gate run by a single 51-inch-diameter hydraulic cylinder, direct-coupled to the gate stem. There was no intermediate mechanism; changing valving simply raised and lowered the piston inside the cylinder, and with it the gate. Sixty-six-inch Chapman butterfly valves, operated by electric motors through Limitorque drives, replaced these gate valves in 1933-34.[40]

Despite their different makers, turbines 5-7 are nearly identicel. They are vertical-shaft, radial-inward-flow, wicket-gate reaction turbines of the Francis type. Each 59-inch-diameter runner is housed within a cast-iron spiral scroll case, visible at the basement level within an open-sided concrete enclosure noted above. Each main generator is direct coupled to the top of the runner axle, with the exciter generator mounted at the top. Units 5 and 6 discharge into simple elbow draft tubes, while unit 7 has a Moody Spreading Cone draft tube. Each turbine has a Kingsbury pressurized-oil-lubricated thrust bearing.* Original turbine installations included manually-operated brakes acting against a drum above the runner; of somewhat unclear intent, these brakes appear designed to prevent runner movement due to leakage thru the wicket gates. In 1965, compressed-air operating cylinders, fed by a large electrically driven compressor, probably replaced the manually-operated brake actuators. Each turbine has a vacuum breaker valve and a 24-inch pressure-relief valve directly opposite the butterfly valve in the casing, discharging directly into the draft tube.[41]

There have been approximately eight replacement runners installed in the three units since 1921, when either unit 5 or 6 was first given a new runner of "better" design. Some runner replacement seems to have been done in a remarkably haphazard manner. In 1941, records on the runner in Unit 6 could not be found. One interesting aspect of the runner replacements are the comparatively large number of companies building the runners -- Baldwin Locomotive Works, BaldwinLima-Hamilton, Wellman-Seaver-Morgan, Barber, and Bagley and Sewell -- as well as the use of four different materials: bronze, cast iron, cast steel, and fabricated stainless steel. The problems encountered with early runner failure, etc., are more likely failures of metallurgy, trash rack design or auxiliary system failure, rather than problems inherent in the turbine designs or manufacture. The Moody Spreading Cone draft tube used on Unit 7, a type developed through extensive testing to increase head and reduce cavitation, may reflect cavitation problems found with units 5 and 6. Unit 7 does seem to have a better maintenance history than units 5 and 6, having required only two replacement runners, as opposed to three each for units 5 and 6.[42]

All three turbines develop 10,400 hp under 270 feet of head, and operate at 327 rpm instead of the design speed of 340 rpm to compensate for the odd 62 1/2-cps generators they are equipped with (see below).

Original Lombard 30,000-ft.-lb oil-pressure governors were modified in 1941 by combining the original operating cylinders more modern Woodward flyball heads and oil pressure pumps. The operating system moves a vertical rod going through the generator floor to the connecting linkage on the wicket gate outer ring. Rotating the rod causes the wicket gates to open or close.[43]

Generators and Electrical Controls

Main new powerhouse generators are vertical Westinghouse A.C. units, rated at 8000 or 8500 KVA, 0.8 power factor, 13,200 volt, 3 phase, 62.5 cps, 349 amp. at 340 rpm, with serial nos. 1981827, 1981828, 2583275. These generators were unusual in having a 22-pole arrangement which gave a non-standard 62.5 cps at

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* Invented by Albert Kingsbury c1912, this successor to the earlier pressurized oil bearings used a series of shoes arranged in a ring with each shoe free to move slightly. In operation the shoes align to form a wedge of oil between the fixed and rotating surfaces, precluding any metal-to-metal contact. Since the oil in the self-forming wedge can support 350 psi unit pressure, the Kingsbury system needed only low-pressure oil supply, eliminating some of the risks associated with high-pressure pumps (see Mead 1920: 253-7).

the designed 340 rpm.* To give 60 cps, the turbines were run at 327 rpm. Exciters are direct connected on top end of generator shaft, and are rated at 125 kw, 125 volt, 1000 amps at 340 rpm. The 1921 addition of Unit 7 accounts for the serial number gap. The KVA output of all three units was originally 8000. By 1959, Unit 5 was rewound to 8500 KVA. Unit 7 was similarly altered c1982. A transmission line to Newport built in 1923 tapped off generator voltage directly without step up.[44]

The existing new powerhouse switchboards are substantially intact, and are good example of the remote control boards of the period. While there has been continual upgrading of protective and control devices, much of the original panels remain. Original synchroscopes (for synchronizing the generators onto the system) are mounted, but the functions are now done by automatic devices. On the generator floor balcony, each generator, exciter and transformer bank has its own panel of Vermont marble with meters for individual machine and total system voltage, load, and other functions. The exciter board south of the main board is particularly intact. Contract specifications indicate that some of the original old powerhouse switchboard meters were incorporated into the new boards, and may remain in place.[45]

Switchboard features include 125-volt hand switches that control distant oil circuit breakers relays and rheostats. There were two types of oil switches initially controlled from the new powerhouse, with a third type used in the substation. Four General Electric F-type, Form K2, 800-amp, 2500-volt OCBs controlled generators 1-4. These consisted of compartments containing the oil tanks, and solenoid-operated contacts mounted in a concrete compartment. A manual control handle was connected to each tank by long levers running under the floor.[46] The solenoids were remotely controlled from the main new powerhouse boards. The switches were probably located in an series of compartments

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* The cps figure of a generator is controlled by the number of revolutions in conjunction with the number of field magnet poles. Adding poles to a given rpm will create a higher frequency, as will adding revolutions to a given number of poles. Poles or revolutions may be varied to change cps, but only certain combinations will yield 60 cps. Designers of turbine-generator sets begin with the ideal rpm for the head and turbine design, and then specify a pole arrangement to give the desired cps. The unusual Trenton Falls arrangement is not well documented, but there are several possible explanations. First, UGEC may have found no standard Westinghouse generator with the right frequency for an already-designed turbine speed. Rather than pay more or wait longer for a special order generator during wartime, UGEC may have accepted mismatched generators running at a slightly lower speed and rating. Second, the generators may have been designed for a different hydroelectric site, or were surplus for Westinghouse, and did not mate with the Trenton Falls turbines, but were purchased to bring the station on line quickly. A final possibility is that UGEC engineers erred, changing turbine specifications after generator construction began, requiring a speed drop (and loss in efficiency) to get 60 cps. The post-war purchase of Unit 7 belies somewhat the time factor in these arguments.

built on the area where the old powerhouse switchboards stood. The oil tanks may have been behind the doors visible in a 1920 historic view, with hand operating levers on the far side.
The lower old powerhouse switch room was probably abandoned about this time, as noted above (page 14). These c1918 old powerhouse switches were probably replaced in 1942 when the old powerhouse was tied directly to the outdoor substation at generator voltage. In 1964 these were again replaced with 1940s-vintage parts taken from other Niagara Mohawk stations, in a configuration of one tank for all three phases mounted behind a door with solenoid and manual trips on the front.[47]

The second type of new powerhouse oil switch was an indoor, electrically-operated OCB, mounted in a long bus structure made up of fourteen concrete compartments in the 13,200-volt upper switch room. These may have been installed in the 1920s, replacing a temporary configuration prior to full outfitting of the new powerhouse.[48] The two generator breakers installed c1918 for switching generators 5 and 6 were Westinghouse type CO-11 solenoid-operated, 600-amp 25,000-volt, designed to manually and automatically isolate the generators from the transformers.[49] In this breaker, a solenoid mounted over the oil tanks moves the contacts via multiple short levers. The solenoid is activated by a 125-volt push-pull button on the switchboard. To prevent chain reaction explosions of breakers, they are placed in concrete compartments with wood or transite access doors. The compartments separated the 3-phase oil tanks from each other, and the whole unit from adjacent ones. Some of the compartments held main feeder breakers, others had station service breakers, and some were left vacant for future expansion. A third machine breaker was added in 1922 to control the output of unit 7. There were additional breakers serving as spares and for station service. All the electric oil switches were equipped with emergency hand operating levers.[50] Four of the original CO-11 breakers are still in service.

East of the upper switch room are the generator field rheostats, providing the fine degree of speed control necessary when alternators are being synchronized into the system. These are motor operated via remote control from the main switchboard, and appear to be the original installation.[51]

The new powerhoue roof has a steel framework supporting wires which come out of the roof of the 13,200-volt switch room, and run from there as catenaries to the outdoor substation via a rectangular steel transmission tower on the bluff.[52]

The remote control technology installed in 1965 was first developed in the mid-1920's and was generally called Supervisory Control. These systems used coded pulses sent over phone lines to activate relays controlling motor- or solenoid-operated switches and valves. As each mechanism cycled, it sent back a signal to the operator to confirm its status. Extensive protective relays sent back data on all malfunctions including overspeed, vibration, overheating, low oil, reverse current, flooding and more. The Trenton Falls system was a "Visacode" type supplied by Westinghouse. A solid-state electronic system was installed in the 1980s.[53]

Crane and Elevator

In 1921, Cleveland Crane end Engineering Company installed the 50-ton crane, with motor travel and lift and with a 10-ton auxiliary hoist. Otis Elevator Company supplied the electrical powerhouse elevator.[54]

Substation

The original outdoor substation was a lattice-girder framework about 160 feet long, 37 feet wide and 33 feet high, arranged in five sections by line destination: future to Ilion, two Utica sections, Rome, and future to Rome Each section consisted of transformers, an OCB, and disconnecting switches. The frame carried the current in bare copper wires to the tops of sets of transformers, then to the tops of OCB sets, and finally to the transmission towers.[55] There were initially seven General Electric 3000-KVA, single-phase transformers which took the 13,200 generator voltage and stepped it up to 44,000 volts.[56] These were oil-cooled transformers, which which began to replace air-blast types c1900.[57] Transformer coils are surrounded by a tank of oil which insulates them from flashovers, and provides a natural cooling effect as the hot oil rises and is replaced by cooler oil from below.

Each bank of transformers were mounted next to a line of narrow-gauge railroad track, on which a four-wheeled car rolled units needing major service to the west end of the yard. Car and transformer were rolled under a hoist house, for transfer of the transformer to road transport.[58] A small oil house at the southeast end of the yard probably contained spare transformer oil and a filter press machine for purifying the insulating oil; a larger structure slightly to the west later replaced this shed. The transformers were isolated from the transmission lines with General Electric KO-26, 45,000-volt, 300-amp OCBs mounted in frameworks. These were replaced in 1927 with Westinghouse G222 50-KV units. Additional breakers were transferred from other stations in 1932 and 1937.[59]

In 1942 a new substation structure was built about 30 feet north of the original yard, with two sets of General Electric 3-phase transformers. This enlargement led to suppression of the air-blast transformers in the old powerhouse, as noted above (page 14). There were other replacements in 1949, 1965, and 1970. In 1959, planning began on a 46- KV rebuild of the outdoor bus structure, with additional steel work including 15-foot-high lattice- and square-framed girders supporting new disconnecting switches. The apparent change in rating from 44 KV to 46 KV was merely on paper, bringing the station up to Niagara Mohawk rating standards. The 1942 feeder tower from the old powerhouse to the substation was demolished in June 1992. A new substation is now being built well south of the yard and will supersede the present facility completely in 1994.[60]

Notes to Parts I and II

1. Niagara Mohawk Power Corporation n.d., and Correspondence files, 2-T7-H21, June 20, 1931 and October 12, 1932.

2. Niagara Mohawk Power Corporation n.d.

3. Rushmore and Lof 1917: 166-92; Hay 1991: 56-60.

4. Niagara Mohawk Power Corporation n.d.

5. Niagara Mohawk Power Corporation n.d., and 2-T7-H12: Brackenridge 1900a, 1900b [plans].

6. ibid,

7. Niagara Mohawk Power Corporation 2-T7-H22: Utica Gas and Electric Company 1917 [plans].

8. Personal communications, Scott Shupe; Niagara Mohawk Power Corporation n.d.

9. Niagara Mohawk Power Company n.d., and 2-T7-H13: Brackenridge 1900c [plans].

10. Niagara Mohawk Power Corporation, 2-T7-H13: Brackenridge 1900d [plans].

11. *Electrical World* 1906: 1031; Niagara Mohawk Power Corporation n.d., and 2-T7-H13: Brackenridge 1900a, 1900b, 1900e, 1900f, and 1900g [plans].

12. Niagara Mohawk Power Corporation n.d., and 2-T7-H13: Brackenridge 1900d, 1900e, 1900f [plans].

13. Niagara Mohawk Power Corporation n.d., and 2-T7-E8: Murray and Orrok 1916b; 2-T7-H13: Brackenridge 1901 [plans].

14. Niagara Mohawk Power Corporation n.d., and 2-T7-H13: Utica Gas & Electric Company 1917, 2-T7-H22: Utica Gas & Electric Company 1917 [plans].

15. Niagara Mohawk Power Company n.d.

16. Horton 1906: 12.

17. Correspondence files, 2-T7-H21, June 20, 1931 and October 12, 1932. Niagara Mohawk Power Corporation.

18. Niagara Mohawk Power Corporation n.d.

19. Niagara Mohawk Power Corporation, 2-T7-H21: I.P. Morris Co. 1906b [plans].

20. Niagara Mohawk Power Corporation n.d., and 2-T7-H21: Pelton Water Wheel 1922.

21. ibid.

22. ibid.

23. *American Electrician* 1898.

24. Thomas 1951: 148; Niagara Mohawk Power Corporation 2-T7-E8: Murray and Orrok 1916b [plans].

25. *Engineering News* 1899.

26. White 1918.

27. General Electric Company 1917: 2, item B; 7; 9.

28. Ibib: 15.

29. Niagara Mohawk Power Corporation n.d.; photograph No. 30 (taken July 17, 1942), file 2177, folder 1; and 2-T7-E8: Niagara Hudson Central Division 1942 [plans]; personal communications, Edward Cooney.

30. Niagara Mohawk Power Corporation n.d.

31. Niagara Mohawk Power Corporation n.d., and 2-T7-H13: Murray and Orrok 19117a-e [plans].

32. White 1918: 1030; Niagara Mohawk Power Corporation n.d.

33. Niagara Mohawk Power Corporation 2-T7-H13: Murray and Orrok 1917b-e [plans].

34. Ibid.

35. Ibid: 1917a-b.

36. Ibid: 1917c.

37. Ibid.

38. Niagara-Mohawk Power Corporation n.d.

39. Carr 1934; Niagara Mohawk Power Corporation n.d., and 2-T7-H3: Utica Gas & Electric Company n.d. [plans].

40. Niagara Mohawk Power Corporation n.d.

41. Ibid.

42. Niagara Mohawk Power Corporation, Correspondence files "Trenton Tests General," "Trenton Hydro Development Unit 5," "Trenton Hydro Development Unit 6," and "Trenton Hydro Development Unit 7."

43. ibid.

44. Niagara Mohawk Power Corporation n.d.; White 1927: 11.

45. General Electric Company 1917: 15, 18.

46. Niagara Mohawk Power Corporation n.d., and 2-T7-E5; General Electric Company 1917 [plans].

47. Niagara Mohawk Power Corporation n.d.; personal communication, Edward Cooney.

48. Cf. Niagara Mohawk Power Corporation 2-T7-E7: Murray and Orrok 1917, Utica Gas & Electric Co. 1924 [plans] with General Electric Company 1917: 48.

49. General Electric Company 1917: 16, 17 Item 1.

50. Ibid: 15; Niagara Mohawk Power Corporation 2-T7-E6: Westinghouse Electric & Mfg. Co. n.d. [plans].

51. Personal communication, George DiStefanis.

52. Niagara Mohawk Power Corporation 2-T7-E31: Murray and Orrok 1917 [plens].

53. Personal communication, Edward Cooney.

54. Niagara Mohawk Power Corporation n.d.

55. Niagara Mohawk Power Corporation 2-T7-E8: Ferguson Steel & Iron Co. 1917, Murray and Orrok 1916a [plans].

56. General Electric Company 1917: 2; Niagara Mohawk Power Corporation 2-T7-E8: Murray and Orrok 1916b [plens].

57. E.g., see HAER No. NY-155: Table 1.

58. Niagara Mohawk Power Corporation n.d.

59. Ibid; General Electric Company 1917: 19.

60. Niagara Mohawk Power Corporation n.d., and 2-T7-E8: Niagara Hudson Central Division 1942, Niagara Mohawk Power Corporation 1959a, 1959b [plans]; personal communication, Edward Cooney.

Part III - Sources of Information

Original Drawings

Niagara Mohawk Power Corporation has over 1600 historic or current plans and drawings, the great majority of them on microfilm, at its headquarters. Nearly 1400 plans document the development of the powerhouses and substation. These materials include many contractor or consulting engineer plans prepared for original construction of the dam, headworks, pipelines, powerhouses, and substation, with a number of plans showing proposed features or equipment not installed. The earliest drawings date from 1899. Most drawings are coded with a system introduced after many of them were originally prepared. The system is based on different site, electrical, hydraulic, and structural components. Drawings used for this documentation, including some reproduced photographically, are listed below with their codes. Other drawings are listed for HAER Nos. NY-155 and NY-155-B. For access, contact:

Environmental Quality Services
Niagara Mohawk Power Corporation
300 Erie Boulevard West
Syracuse, NY 13202
ATTN (1993): Scott D. Shupe, Environmental Analyst, tel. 315/428-6616

<u>No Codes or Illegible Codes</u>
Niagara Mohawk Power Corporation
1989a Constructed West Canada Creek Project. Trenton Development. Detail Map. License Amendment Exhibit G, Sheet 5A.

1989b Constructed West Canada Creek Project. Trenton Development. Powerhouse. Plans and Sections. License Amendment Exhibit F, Sheet 6A.

<u>2-T7-E5: Power Transformers & Accessories</u>
General Electric Company
1915 Outline of Oil "Switch Type "F"... No. K1802576.

<u>2-T7-E6: Switching Equipment</u>
Westinghouse Electric & Mfg. Company
n.d. Cir. Bkr.-Oil Type COII-Elec. Oper.-Cell Mtg.-Non-Auto/Distant Control-3p S.T.-600-2000A.-25000 V./Out Line. No. 700508.

1917 Trenton Falls Hydro Plant/Cir.Bkr.-Oil Type CO II/Elect. Oper.-1500 v./Gen'l Dwg. No. 600514.

1941 Cir Bkr Air Type - 2500 v Out Line. No. 9A-4692

<u>2-T7-E7: Bus & Switch Structure - Indoor</u>
Murray, Thomas E./George A. Orrok
1917 Utica Gas & Electric Co./Trenton Falls/Electrical Equipment-Cross Section AA." No. 43878.

Utica Gas & Electric Company
1924 Trenton Falls Station/Bus and Oil Circuit Breaker Compartments in 13,200 V. Switchroom. No. 24832.

2-T7-E8: Bus & Switch Structure - Outdoor
Ferguson Steel & Iron Co. [Buffalo, NY]
1917 Outdoor Structure/Utica Gas & Electric Co./Trenton Falls, N.Y. No. 741-E3.

Murray, Thomas E./George A. Orrok
1916a Utica Gas & Electric Co./Trenton Falls/Section showing general layout of electrical apparatus. No. 43246-2.

1916b Utica Gas & Electric Co./Trenton Falls/General Layout of Electrical Apparatus. No. 43247

Niagara Hudson Central Division/Central New York Power Corp.
1942 Trenton Falls Hydro Station/Outdoor Bus Structure/Steel Framing-Plans. No. 30137.

Niagara Mohawk Power Corporation
1959a Trenton Falls Hydro Station/46 Kv. Rebuild/Outdoor Bus Structure/Electrical Elevation K-K. No. C-10474-C.

1959b Trenton Falls Hydro Station/46 Kv. Rebuild-Outdoor Bus Structure/ Steel Framing-Elevation & Section. No. C-10843-C

2-T7-E9: Switchboards & Accessories
General Electric Co.
1917 Switchboard/(Front View) Exciter Board/Utica Gas & Electric Co./ Trenton Falls Station. No. P-1826512.

2-T7-E31: Towers, Poles & Fixtures
Murray, Thomas E./George A. Orrok
1917 Trenton Falls. Outline of Steel Structure for supporting 13200 V. Cables. No. 43557.

2-T7-H0: General
Brackinridge, W.A.
1901 Utica Electric Light and Power Company. Map showing location of Dam, Pipeline and Power House. No. R-106.

2-T7-H3: Intake (Sluice Gates)
Utica Gas & Electric Company
n.d. Trenton Falls Extension. Profile of 12' Dia. Pipe Line. No. S-90.

2-T7-H12: Powerhouse - Substructure

Brackinridge, W.A.

1900a Utica Electric Light and Power Company. Longitudinal Sections of Power House Foundations. No. 21121.

1900b Utica Electric Light and Electric Company. Cross Sections of Power House Foundations. No. 98.

1900c Utica Electric Light and Power Company. Plans showing Stones for Dynamo Base. No. 103.

2-T7-H13: Powerhouse - Superstructure

Anonymous

1942-44a Trenton Falls Powerhouse. Building Inspection. General Plan.

1942-44b Trenton Falls Dam. Building Inspection. General Plan.

Brackinridge, W.A.

1900a Utica Electric Light and Power Company. Details for Power House Doors. No. 94.

1900b Utica Electric Light and Power Company. Detail for Windows. No. 118.

1900c Utica Electric Light and Power Company. Plan showing Floor over Receiver. No. 148.

1900d Utica Electric Light and Power Company. Plan showing Steel Frame Work for Power House. No. A-82.

1900e Utica Electric Light and Power Company. Detail of Panel in Power House. No. R-102.

1900f Utica Electric Light and Power Company. Cross Section and End Elevation of Power House. No. 20377.

1900g Utica Electric Light and Power Company. Side Elevation of Power House. No. A-91.

1901 Utica Electric Light and Power Company. Plan showing Installation of 4-1700 H.P. Units. R107. [filmed in 2 parts]

Murray, Thomas E./George A. Orrok

1917a Trenton Falls/Addition to Station/Elevations. No. 43802.

1917b Trenton Falls/First Floor Plan. No. 43803.

1917c Trenton Falls/Plans of Second Floor, Roof, Main Building & Stair Tower Roof. No. 43804.

1917d Trenton Falls/Transverse and Longitudinal Sections. No. 43805.

1917e Trenton Falls/Longitudinal Section Looking East. No. 43807.

Utica Gas & Electric Company
1917 Trenton Falls Station. Floor Plan of Power House as existing Jan. 6, 1917. No. 2403-1.

Utica Steam Engine and Boiler Works
1922 Columns & etc. No. 26256.

2-T7-H21: Turbines & Governors

Anonymous
1900 1700HP Turbines for Utica Electric Lt. & Pow. Co. No. 5670.

Brackinridge, W.A.
1900 Utica Electric Light and Power Company. Plan showing Base for 1000 K.W. Dynamo. No. R84.

1904 The Utica Gas and Electric Company. Sketch showing arrangement of Tachometer on top of shaft of 1000 K.W. Generator. [no no.]

General Electric Company
1900 Outline/Generator 2200 v. No. 98558-501.

I.P. Morris Co.
1900a Utica Electric Light & Power Co./1700 HP Turbine Wheels (proposed). No. 5672.

1900b Utica Electric Light & Power Co./1700 HP Turbine Wheels (proposed). No. 5686.

1900c General Arrangement of Governor/1700 HP Turbine/Utica Electric Light & Power Co. No. 5751.

1900d General Arrangement. 1700 HP Turbines, for Utica Electric Power & Light Co. No. 5753. [also a 1901 version, 2 copies]

1900e Wheel and Distributor/100 HP Turbine for Utica Electric Light & Power Co. No. 5864.

1900f Casing and Cover/100 HP Turbine for Utica Electric Light & Power Co. No. 5865.

1900g General Arrangement/100 HP Turbine for Utioa Electric Light & Power Co. No. 5892.

1902 Arrangement of Governor/1700 HP Turbine for Utica Electric Light & Power Co. No. 6553.

1903 General Arrangement/100 HP Turbine for Utica Gas & Electric Co. No. 6811.

1906a 100 HP Turbine for Utica Gas & Electric Co./Details of Operating Cylinder. No. 8443.

1906b 100 HP Turbine for Utica Gas & Electric Co./Regulating Valve. No. 8467.

1907 Glocker-White Governor for Utica Gas & Electric Co./General Arrangement, No. 9783.

1913 Order M1859. Wheel/100 HP Turbine for Utica Gas & Electric Co. No. 6800.

Lombard Governor Company, The
1914 Horizontal Governor/45,000 Ft. Lbs. No. 9-A-38.

Pelton Water Wheel Co.
1899 Proposed Arrangement of Pelton Water Wheels for the Utica Electric Power & Light Co. [no no.]

1900 24" Motor geared to line shaft for operating gate valves. No. 7.

1902 Two 27/2 Wheels with 4" Simple Nozzles for direct-connection to a 75 K.W. Generator. No. 16.

1914 Assembly Drg. of Pelton Oil Pressure Governor Type E. No. A1861.

Platt Iron Works
1917 Trenton Falls/Sketch of 57" Wheel Setting/Utica Gas & Electric Co. No. 60312.

Niagara Hudson Central Division/Utica Gas & Electric Co.
1932a Trenton Falls Station Units 1-4/General Arrangement of Turbine and Governor. No. 11372.

1932b Proposed Motorization/Speed Control Equipment for Units 1-4 Incl. at Trenton Falls. No. 20004.

<u>2-T7-H22: Auxiliary Water Air & Oil Systems</u>
Utica Gas & Electric Company
1917 Trenton Falls Station. Plan of Basement of Existing Power House showing Piping, etc. No. A-2440-0.

<u>2-T7-M5: General Survey and Maps</u>
Anonymous
1935 Trenton Falls Hydro-Plant/Location Map of Buildings and Structures/ Oct. 15, 1935. Dwg. No. 21787.

Historic Views

There are few photographs available for Trenton Falls Station before the construction of the new powerhouse. Some appear in *Electrical World* 1906, and a small number are in private hands. Niagara Mohawk Power Corporation has over 1000 historic views at its headquarters, in several different collections, including a small number of pre-1917 views. Aside from published views in White 1918, new powerhouse construction photographs appear rare, but after c1919-20 the Niagara Mohawk collection provides a very full record of changes made at the station. For access, see Original Drawings, above.

Many Niagara Mohawk Power Corporation employees provided valuable information during research for this documentation from March to May 1993. At the Syracuse headquarters, engineers, designers, and analysts included Paul Bernhardt, Robert Easterly, Joseph Flood, Samuel Hirschey, Jacob Niziol, Gary Schoonmaker, Robert Shantie, Scott Shupe, and Joseph Viau. Edward Cooney, Harbor Point control supervisor, and past or present Trenton Falls Station operators George DiStefanis, Robert Dolan, Robert Jones and Wayne Richard shared years of personal station management experience.

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Sources Not Yet Investigated

More intensive use of available plans and historic views might reveal additional structural or station history details, presumably minor in nature. Further interviews with past and present station operators would yield useful information on equipment performance or hydraulic problems since at least c1945, as well as first-hand perspectives on operator staffing and organization patterns.

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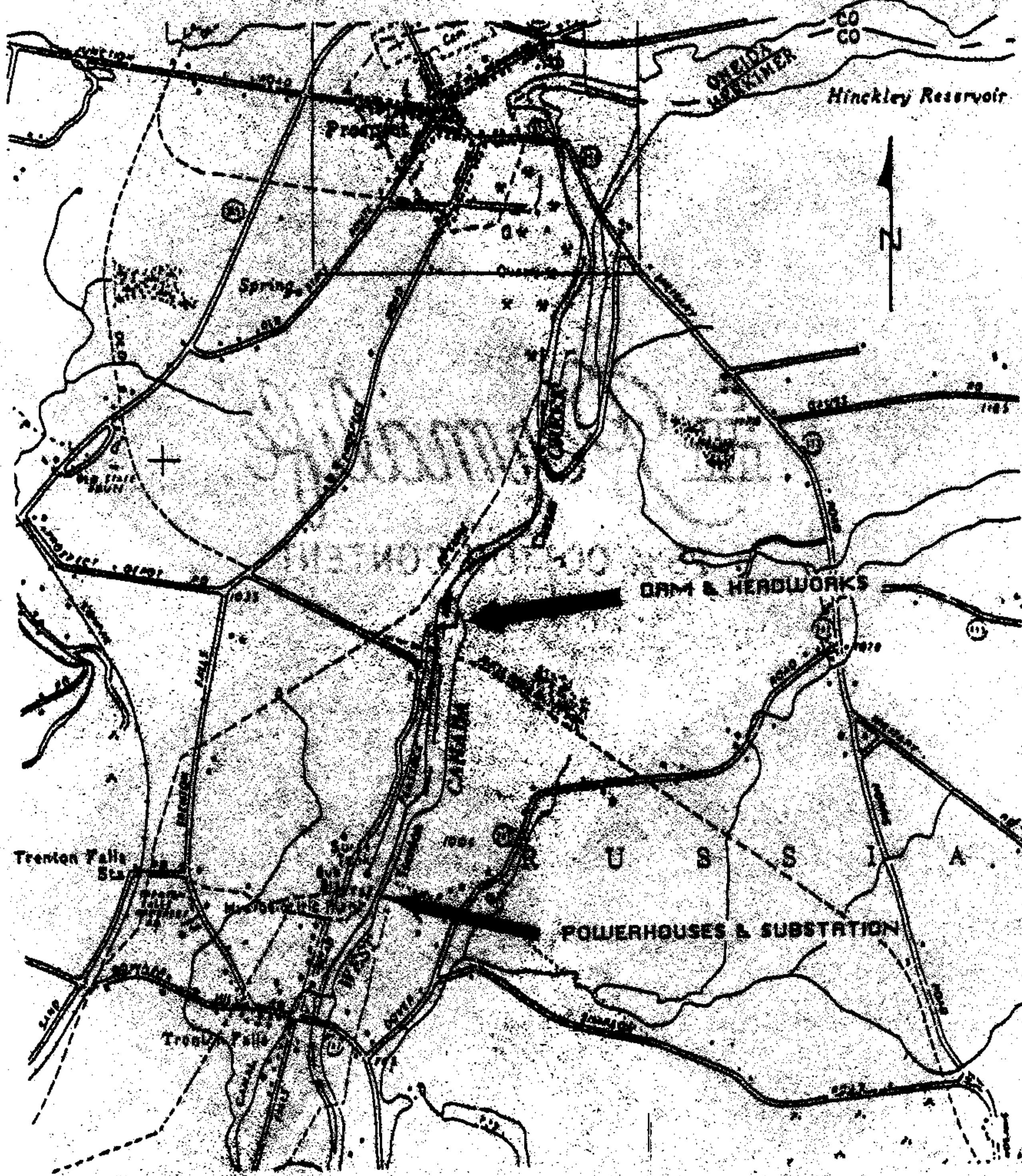

TRENTON FALLS HYDROELECTRIC STATION ON WEST CANADA CREEK
(base map: Remsen U.S. Geological Survey 7.5-Minute Quadrangle Sheet)